ABSTRACTS (MASTER THESIS)

Development of a thermoplastic nanocomposite using a wood cell wall nanostructure

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Introduction

Wood cell walls are natural nanocomposites. Cellulose nanofibers (CNFs) are fillers and hemicellulose and lignin are matrix substances. The wood cell wall structure is well-ordered at the nanoscale and CNFs have significant advantages as fillers including high strength and low thermal expansion properties that derive from the extended cellulose molecular chain crystal structure. Hence, the development of a novel thermoplastic material using the wood cell wall nanostructure was studied.

For this purpose, CNF covered with lignin (lignoCNF) was prepared and a selective chemical modification of the hydroxyl group of lignoCNF was carried out. The aim was to enhance the thermoplasticity of the matrix without damaging the cellulose crystal structure.

Materials and Methods

LignoCNF was prepared from softwood Bleached Chemi-ThermoMechanical Pulp (BCTMP) using a grinder, based on a previous report[1)]. After solvent displacement into N-methylpyrrolidone, in the presence of pyridine, esterification using acetic anhydride and n-octanoyl chloride was performed at 60°C for 12h. Different degrees of substitution (DS) of the esterified lignoCNF were obtained by changing the amount of reagent. The samples were freeze-dried and compression molded at 160°C or 200°C. The crystallinity, dynamic viscoelasticity and linear thermal expansion of the molded samples were studied using X-ray diffractometry (XRD), Dynamic Mechanical Analyses (DMA) and Thermo-Mechanical Analyses (TMA), respectively.

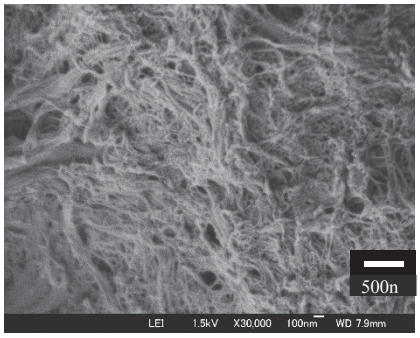

Figure 1. FE-SEM image of lignoCNF.

Results and Discussion

LignoCNF of 20 nm to 1 μm in size was obtained after 3 passes of grinder treatment (Figure 1). This lignoCNF contained 25% lignin (klason lignin), which is similar to the original softwood.

Esterification improved the thermoplasticity of the lignoCNF. Upon octanoylation treatment, the thermoplasticity was drastically improved above DS=0.6, which means that 20% of the surface hydroxyl groups of the lignoCNF were substituted (Figure 2a and c). However, its thermal expansion was quite high. In the case of acetylation, the substitution of 30% of the hydroxyl group (DS=0.8) enabled a close adhesion between the lignoCNF elements after compression at 200°C and 50MPa (Figure 2b and d). The crystal structure of the CNFs was maintained and a low coefficient of thermal expansion (CTE) of 30 ppm/K was obtained, which is similar to the CTE of aluminum alloys.

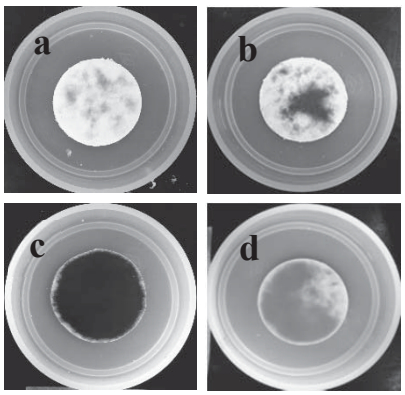

Figure 2. After compression molding at 50MPa. a : untreated, 160°C, b: untreated, 200°C, c : octanoylation(DS=0.6), 160°C, d : acetylation(DS=0.8), 200°C.

References

[1] Abe, K, F. Nakatsubo and H. Yano, "High-strength nanocomposite based on fibrillated chemi-thermomechanical pulp," *Composite Science and Technology*, vol. 69, no. 14, pp. 2434-2437, 2009.